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# Breeding Behavior of Fiber in Sugarcane.

Hridaya Nath Singh
*Louisiana State University and Agricultural & Mechanical College*

# BREEDING BEHAVIOR OF FIBER IN SUGARCANE

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TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

## ABSTRACT

Material used in this study consisted of the clonal progenies of seven crosses in sugarcane. The original crosses were made in November - December, 1951, at Canal Point, Florida. The entire material was maintained at Houma, La., by Mr. Leo P. Hebert. In November, 1955, the clones, which were in the first stubble crop, were harvested and the data for the present study were obtained.

From the bagasse of each clone, two samples were taken at random and were washed in the running water until sucrose free. Then they were dried to a constant weight which gave fiber in the sample, from which fiber content in bagasse and cane was calculated.

The method of duplicate sampling of bagasse for fiber determination proved to be highly accurate and reliable. The average coefficient of variation between duplicate samples was 1.8 per cent. The plot to plot variation was also low, with a coefficient of variation of 5.1 per cent, indicating that environmental variation among the unreplicated five foot plots of the clones was relatively small.

Significant positive correlations of about .70 were found in all crosses between per cent fiber and per cent bagasse in the cane, indicating that selection for low bagasse per cent would be moderately effective in obtaining low fiber types.

No correlation was found between per cent fiber and erectness of

stalks. In some crosses, low but significant positive correlations occurred between fiber content and number of stalks per stool. This positive correlation will cause some difficulty when selection is practiced for low fiber content and high stalk number.

There were significant positive correlations between per cent of fiber and sucrose content. This positive association will cause difficulty in breeding programs in obtaining clones with high sucrose and low fiber content.

Fiber per cent in the cane is quantitative character and shows absence of dominance. The number of genes governing this character could not be determined because of heterozygous condition of parents and genes on chromosomes of S. spontaneum and S. officinarum will not undergo normal Mendelian segregation. There was high frequency for the recovery of the parent types. Fiber content also showed transgressive segregation which gave clones 2 - 3 per cent lower in fiber than low fiber parent while some were higher than high fiber parent.

A close relationship between fiber content of parents and progeny indicated that the behavior of progenies can be predicted reliably from the knowledge of the fiber content of parents.

The results led to the conclusion that a high fibered variety can be used in crosses provided the other parent has low fiber percentage. When both the parents are intermediate, the progeny will be mediocre. If both the parents are high in fiber, the progeny will be useless for obtaining low fiber types.

# INTRODUCTION

The International Society of Sugarcane Technologists has defined fiber in sugarcane as "the dry, water insoluble matter in cane." It is made up of cellulose (49.00%), pentosans (32.04%), lignin (14.93%), protein (1.94%), ash (1.68%) and fat and wax (0.41%). It is modified by a number of factors such as cane variety, age at harvest, class of cane (plant or stubble) and climatic conditions under which the crop was produced. According to some investigators it increases from the base of the stalk towards the top, in nodes as well as internodes. But according to Kerr and Cassidy (1928) fiber per cent in cane decreased progressively from base up to middle internodes while in top internodes it was more than even in the base.

Before 1927, the average fiber per cent in cane rarely exceeded ten per cent. Sometimes the average of the season was as low as nine per cent. Since that time, the fiber in cane has increased appreciably. Now in some countries, it is common to get fiber of 16 per cent or above. The increase in fiber has caused a progressive increase in bagasse percentage resulting in less sugar per ton of cane.

The estimation of fiber per cent in cane assumes varying importance in factories as well as, to a certain extent, to cane breeders. Moreover, the tedious and time consuming nature of fiber determination in cane is such that it is a problem to find out a convenient way to estimate, from a relatively small number of stalks, the average fiber content which can be of practical importance to both.

Studies on breeding behavior of different characters in sugar cane are comparatively rare, reasons being, uncertain flowering, interests of personnel, polyploidy, size of flower and sterility. In addition, there has been a common belief that the behavior of progenies was so varied that it was very difficult to give a generalized breeding behavior of the different cane varieties. This is the reason for the dearth of investigations and its publication in the past. But the recent publications as well as present work explode this belief about sugarcane breeding.

These facts led to the undertaking of an extensive study on breeding behavior of fiber in sugarcane. The studies included in this dissertation were taken up to find out the breeding behavior of fiber in sugarcane and also its association, if any, with other characters. The results obtained should be useful both to breeder and factory people.

Clonal progenies of seven crosses, in which parents differed in respect to fiber content, were studied. Fiber per cent was measured for each clone individually. Correlation coefficients of fiber with other characters were calculated. They were as follows: bagasse per cent in cane, fiber per cent in the bagasse, number of stalks per stool, erectness, stalk diameter, field brix and sucrose.

## REVIEW OF LITERATURE

Comparatively few papers have been published concerning the inheritance of different characters in sugarcane. These are reviewed in the following paragraphs.

Deer (1921) stated that the most practical method to estimate fiber in cane is to wash the bagasse in cold water. He immersed the bagasse for a period of time in a linen bag in a stream of water, followed by subsequent pressure and drying. The time required could be much shortened by the use of a hydraulic or powerful screw press. After each pressing the wad of bagasse was loosened, additional water placed in the pot and pressure again applied until extraction was complete. He has also given the composition of sugarcane fiber which was as follows:

| | Pith Per Cent | Bundles Per Cent | Rind Per Cent |
|---|---|---|---|
| Ash | 1.68 | 3.58 | 1.64 |
| Fat and wax | 0.41 | 0.72 | 0.98 |
| Cellulose | 49.00 | 50.00 | 51.00 |
| Pentosans | 32.04 | 28.67 | 26.93 |
| Lignin | 14.93 | 15.03 | 17.17 |
| Protein | 1.94 | 2.00 | 2.19 |

Davies and Yearwood (1946) suggested a simplified method of fiber estimation from bagasse. They took two 100-gram bagasse samples in linen bags, washed in running water until sucrose free (24 hours) and dried in an oven at 105° C. From this dry weight of fiber, fiber in cane was calculated.

Spencer and Meade (1917) reported a chemical test known as Alpha-Naphthol Test for traces of sugar in water. In 2 c.c. of water to be tested add 5 drops of a 20 per cent alcoholic solution of alpha-naphthol, then by means of a pipette reaching to the bottom of the tube add 5 c.c. of concentrated sulfuric acid. If sucrose is present, a violet ring appears at the junction of two liquids. They suggested that acid must be strictly chemically pure and alpha-naphthol solution should be fresh. If the solution contains as little as one part of sucrose per million parts of water a very pale lilac tint is visible while one part in ten thousand gives almost a black ring.

Keller (1956) reported a method for separation of tougher fiber from bagasse. This method separated soluble solids as well as pith. He said that the earlier rod mill method used was costly and the loss of tougher fiber was also high. The other method was a wet separation process. Here the separation of fiber had been more complete but the cost of power and handling of excessive wet fiber was relatively high. In order to overcome, most, if not all, of the objections he suggested the use of modified swing hammer mill method. His suggestion was for large scale commercial use.

Kerr and Cassidy (1938) reported the fiber content of different internodes of plant as well as stubble cane within a stalk.

| | Top internodes | | | | Middle internodes | | | | Bottom internodes | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Plant | 12.16 | 10.88 | 9.90 | 9.93 | 9.18 | 9.21 | 9.31 | 9.48 | 9.53 | 9.74 | 9.93 | 10.7( |
| Stubble | 11.28 | 11.17 | 10.43 | 9.75 | 9.75 | 9.66 | 9.83 | 10.13 | 10.25 | 10.31 | 10.35 | 11.7Ɛ |
| Ave. | 11.74 | 11.02 | 10.15 | 9.53 | 9.45 | 9.43 | 9.56 | 9.79 | 9.88 | 10.01 | 10.13 | 11.22 |

Almeida and Canseglieri (1941) reported that fiber in plant cane varied from 9.6 per cent at 11 months to 14.8 per cent at 20 months. The fiber per cent of stubble cane also increased from an average of 12.67 per cent in plant cane at the usual harvest time to 12.85 per cent in the first and 13.22 per cent in the second stubble crop. Stools that had flowered contained more fiber than non-flowered canes. Within a stalk fiber increased from the foot of the stalk towards the top, in nodes as well as in the internodes.

As early as 1918, Gowgill (1918) recorded variation occurring among the clones of the same parentage. Later, Cheesman (1927) supported this view.

Venkatraman (1927) reported that these variations were so extensive that they rendered definite genetic laws of inheritance in sugarcane unlikely. He offered many reasons for this uncertainty, some of them were:

(1) the occurrence of great variations among the clones of the same parent even though flowers were protected from foreign pollen. On this basis he doubted the very purity of the varieties used.

(2) though clones were raised artificially there is no certainty about parentage, because of the size and number of the flowers and the inability to employ either emasculation or bagging in cane breeding operations.

(3) further, the knowledge of the mode of inheritance and segregation of characters requires more than one generation of study. But this is not always possible due to non-flowering of hybrids or to sterility in plants.

Dutt (1951) reported the inheritance of pithiness in sugarcane. He conducted progeny tests of 21 different combinations with one hundred plants in each cross. Crosses were: (1) pithy x pithy; (2) non-pithy x pithy; (3) pithy x non-pithy; (4) non-pithy x non-pithy. In the case of the first type of combination all plants were pithy while the presence of one non-pithy parent resulted in considerably less pithiness. Where both parents were non-pithy the progenies were non-pithy. A considerable decrease was recorded in pithiness when the non-pithy parent was the pollen parent.

Loh et al (1952) recorded that tillering and diameter were associated with the female parent while the height of the stool was usually associated with the male parent. They further stated that there was a statistically negative significant correlation between tillering and stalk diameter. Small barrel and good tillering showed high correlation, r = .99487 (N 3, P 1%, r = .9587), while big barrel and poor tillering showed also a significantly high correlation with r = .98564.

Warner (1953) reported that a practice of recurrent selection has been effective in concentrating genes indispensable to commercial cane. In support of his statement he gave an example: "P.O.J. 2878, one of the parents of 32 - 8560, has a current selection ratio of 1/54,141 while 32 - 8560 has improved ratio 1/10,859. Offspring of 32 - 8560, e.g. 37- 1933, 39 - 7028 and others show considerably better records than 32 - 8560." He further stated "Members of the genus Saccharum, including sugarcane and its wild relatives, behave genetically like other plants. We have no reason to believe that sugarcane is in any way unique in respect to the fundamental principles of genetics, established, as they have been, from the study of insects and other animals, and of fungi and higher plants. It follows therefore, that any approach to the breeding of sugarcane must be formulated on an adequate understanding of basic genetic principle." He has also given an elaborate account of breeding behavior of parent canes such as Co. 213, P.O.J. 2878, S. spontaneum (Coimbatore), S. robustum (Port Morsby), Chunee hybrids, Hawaiian Uba, Badila, 32 - 1063, 32 - 6705, 32 - 8560 and 37 - 1933. From the behavior of these he concluded that it was very difficult to give a generalized breeding behavior of heterozygous parents.

Brandes and Klaphaak (1925), Jeswiet (1927), Brandes and Sartoris (1936) and McMartin (1949) stated that varieties belonging to S. officinarum either from selfing, natural occurring or crossing of two such varieties gave progenies susceptible to mosaic disease. Brandes and Klaphaak (1925) and Jeswiet (1927) also reported that Chunnee, a variety of S. barberi, and its progeny were susceptible to mosaic. Crosses between Chunnee and varieties of S. officinarum gave progenies which were susceptible to mosaic. However, Chunnee and varieties derived from crosses with Chunnee showed considerable tolerance to mosaic and consequently were not injured greatly by the disease. They stated that S. spontaneum is completely immune to mosaic. This apparently refers to the Java form. Also, Kassoer, a natural $F_1$ hybrid between S. officinarum and the Java form of S. spontaneum was immune. Furthermore, more than 1000 $F_2$ plants from selfing of Kassoer were all immune, without exception. They concluded that immunity and susceptibility are transmitted as simple unit characters, but did not cite any genetic data to support this conclusion. When Kassoer was crossed back to S. officinarum, some susceptible segregates were obtained. They stated that the "quality" of immunity is proportional to the amount of S. spontaneum germ plasm that is present. When this was increasingly diluted (by backcrossing to S. officinarum) an increasing proportion of susceptible segregates were obtained. Such varieties as P.O.J. 2714, P.O.J. 2722, P.O.J. 2725 and J. 70 were derived from two backcrosses to S. officinarum. None of these were immune to mosaic but all were highly resistant. Brandes and Klaphaak (1925) further stated that some of plants containing 1/8 of S. spontaneum germ plasm were not immune to mosaic.

Brandes (1931) reported that crosses between varieties of S. officinarum and S. spontaneum from Java gave apparently immune plants in the $F_1$ and a great number of mosaic resistant plants in the $F_2$ generation. In one study, nine of 650 $F_2$ plants were infected and in a second study two plants among about 70 tested were infected. On the basis of this result he stated that it would be safe to interpret that susceptibility to mosaic was a recessive character.

He further stated that susceptibility or resistance to mosaic in sugarcane was not due to a single pair of alleles because, in certain crosses, he observed that there was a wide range of response, from susceptibility to complete immunity, which he attributed to multiple genes.

Rands, Abbott and Summers (1935) reported the results of five crosses. When they crossed (1) D - 95 X S. spontaneum (Tabongo collection), (2) D - 95 X S. spontaneum (Pasoeroean), (3) D - 95 X S. spontaneum (Importation

238), (4) D - 95 X *S. spontaneum* (Importation 470) and (5) Otaheite X *S. spontaneum* (Importation 238) they found 6.8, 9.5, 1.4, 0.0, and 22.8 per cent mosaic susceptible plants, respectively, in $F_1$. But on the basis of this result they questioned whether the infected seedlings were hybrids. On the other hand they have concluded that these five crosses, involving susceptible noble varieties and various *S. spontaneum*, showed incomplete dominance for reaction to mosaic.

Further they have given the results of three series of backcrosses made by Dr. G. B. Sartoris. The results of the one of these series was as follows: In this series the pollen parent used was apparently immune to mosaic while female parent was susceptible. When D - 74 (very susceptible) was crossed with U. S. 1694 (never developed mosaic and was practically immune to root rot) it gave C. P. 27 - 38 with 36.4 per cent mosaic infection. It was listed as mosaic-free. This was backcrossed with Co. 281 (Co. 281 X C.P. 27 - 38) which was graded as very susceptible to mosaic. This cross gave C. P. 28 - 44 which had 34.6 per cent mosaic infection. This variety was graded as mosaic-free and possessed other valuable characters of U. S. 1694. In the third backcross (Co. 281 X C. P. 28 - 44) they observed that progeny had 66.2 per cent mosaic infection. The same trend was maintained in the other two series of backcrosses. They have concluded that mosaic susceptibility was apparently increased as a result of backcrossing.

In the second set of studies they tried to find out whether resistance or susceptibility to mosaic and red rot was associated with each other. They took Co. 281 which was highly resistant to red rot but was susceptible to mosaic, U. S. 1694 which was very susceptible to red rot but was apparently immune to mosaic and P.O.J. 2878 was moderately susceptible to red rot and was fairly susceptible to mosaic. The progenies of both the crosses (1 x 2 and 1 x 3) showed an independent behavior. The first cross gave progeny which had 18 per cent plants resistant to mosaic and commercially resistant to red rot while the second cross gave 32 per cent plants resistant to mosaic and commercially resistant to red rot. On these results they have concluded that resistance or susceptibility to mosaic and red rot was independently inherited.

Abbott et al (1936) reported the results of 45 crosses between different varieties of sugarcane. Some of the crosses gave progenies up to 91.4 per cent mosaic symptoms.

Inniss (1944) stated that one of 21 clones resulting from the cross between two noble varieties, was resistant but not immune to mosaic.

Azab (1952) reported that at least three dominant complementary genes, probably along with a minor modifying factors, which affect the degree of expression, were responsible for the resistance to mosaic disease in sugarcane.

Abbott (1938) stated that unless a variety possessed a satisfactory degree of resistance to red rot, other measures would be ineffective in many years. He has also reported that there was surprising rarity of satisfactory resistance to red rot and few, if any, cane varieties were so resistant to this disease that their resistance could not be broken down by unfavorable soil and weather conditions. The variability of the fungus causing red rot was so great that it made more difficult to develop cane varieties that were resistant to all forms of this fungus.

Azab (1952) reported that red rot resistance in sugarcane was governed by one or a few dominant resistant genes from *S. spontaneum* plus a dominant inhibitor gene from *S. officinarum*. A group of minor modifying genes may also influence the degree of expression of the disease. Genes governing resistance in the nodes were different from those governing the resistance of the internodes.

## MATERIALS AND METHODS

The material used in this study consisted of the clonal progenies of seven crosses in sugarcane: 1. cross 11 (C. P. 36-105 x C. P. 34 - 139), 2. cross 15 (C. P. 38-34 x C. P. 36-105), 3. cross 32 (C. P. 36-105 x C. P. 30-24), 4. cross 49 (C. P. 29-103 x C. P. 33-224), 5. cross 72 (C. P. 33-224 x C. P. 48-126), 6. cross 74 (C. P. 43-64 x 44-154) and 7. cross 148 (C. P. 43-33 x C. P. 47-191). The original crosses were made in November-December, 1951, at Canal Point, Florida. The seeds from these crosses were sown in the greenhouse. The young seedlings were sprayed with mosaic inoculum and seedlings showing resistance to mosaic disease were selected and put in the field in single plant hills in April, 1952, and labelled. The number of plants per cross was relatively large. In the fall of 1953 up to 150 plants of each cross were established as clones in 5 foot plots of each with their respective parents each at four places. In part of the crosses there were fewer plants than 150. The entire material was maintained at Houma, Louisiana, by Mr. Leo P. Hebert for his Ph.D. dissertation. In November 1955, the clones, which were in the first stubble crop, were harvested.

Only clones which had three or more stalks were harvested. Where available, five stalks were harvested from each clone. Those which had only three or four stalks per clone were also harvested while clones with less than three stalks were rejected. On this basis the number of clones in each cross which were harvested were as follows: cross number 11 had 83, cross 15 had 133, cross 32 had 144, cross 49 had 108, cross 72 had 138, cross 74 had 143 and cross 148 had 96.

After harvesting, each clone was tagged with the number listed on the plot-stake. The clones were moved to a shed and fresh weight of each was determined and recorded. Stalks of each clone were run twice through an experimental mill using 32 tons or 2.286 tons per linear inch of hydraulic pressure. Care was taken to keep the top roll floating as much as it was possible by uniform feeding. Bagasse from each clone separately was collected in paper bags, weighed and the weights were recorded. After milling, bagasse samples were moved to Baton Rouge, Louisiana and stored in a ventilated room.

In estimating fiber percentage the bags of bagasse were again weighed. From the bagasse of each clone, two samples weighing approximately 100 grams were taken at random for fiber estimation. Each sample was weighed and put into a numbered cloth bag. The samples in cloth bags were washed in running water. For this purpose, two steel drums measuring 36" x 24" each were used. Each drum could hold 50 samples at a time. Both drums were fitted with one top inlet and one bottom outlet. A constant and continuous inlet and outlet of cold (tap) water was maintained throughout the experiment. The cloth bags with bagasse were kept below the water level. Drainage water was tested chemically for the presence of sugar by the following method: 5 drops of a 20 per cent alcoholic solution of alpha-naphthol was added to 2 c.c. of drainage water in a test tube. Then by means of a pipette and reaching to the bottom of the test tube 5 c.c. of concentrated sulfuric acid was added. In the presence of sucrose, a violet zone or ring appears at the junction of the two liquids. The intensity of the color depends on the sucrose present. When the drainage water contained as little as one part of sucrose per million parts of water, a very pale lilac tint is visible, while one part in ten thousand gives a black ring due to charring of the sugar by the acid. The bags of bagasse were kept in running water until no color was visible in tests of the drainage water. Approximately, it took 3 1/2 to 4 days to wash the sugar out of the bagasse. When the drainage water became free of sugar, the samples were taken out of the water and put into a corn drier for about 3 days to reduce the moisture content. After this, the samples were transferred to an electrically heated oven at $100^{\circ}$ C. for 24 hours. Then they were removed and weighed. The samples were again placed in the oven at $100^{\circ}$ C. for 6-12 hours and reweighed. When they reached a constant weight, it was assumed that only fiber remained. From the fresh weight of cane, total weight of bagasse, weight of bagasse sample and dry weight of fiber, per cent of fiber in the cane and in the bagasse were calculated.

The following statistical analyses were made from the entire data:

1. Frequency distribution of the populations for fiber per cent in different crosses.
2. Population mean of each cross.
3. Parent mean in each cross.
4. Range of fiber per cent in cane in each cross.
5. Analysis of variance and Least Significant Difference for fiber per cent in cane of each cross.
6. Correlation Coefficient were calculated for:

   (a) fiber per cent cane and bagasse per cent cane.

   (b) fiber per cent cane and fiber per cent bagasse.

(c) fiber per cent cane and number of stalks per stool.

(d) fiber per cent cane and erectness.

(e) fiber per cent cane and stalk diameter.

(f) fiber per cent cane and field Brix.

(g) fiber per cent cane and sucrose.

Mr. Leo P. Hebert provided the data on number of stalks per stool, erectness, stalk diameter, field Brix and sucrose.

The correlation coefficient was calculated from the following formula:

$$r = \frac{S(xy) - (Sx)(Sy)/n}{\sqrt{S(x^2) - (Sx)^2/n \quad S(y^2) - (Sy)^2/n}}$$

where r - the correlation coefficient.

S - sum of

x - measurement of one variable.

y - measurement of other variable.

n - number of observation of each variable.

## RESULTS AND DISCUSSION

The results can be divided logically into three categories, (1) reliability of fiber determinations, (2) correlations of fiber percentage with other characters and (3) breeding behavior of fiber percentage among the seven crosses.

### Reliability of Fiber Determinations

Before valid use could be made of the fiber measurements among the clones it seemed desirable to determine the degree of accuracy or reliability in the measurements of fiber content and the degree of plot to plot variation among clones that was caused by environmental factors. In order to measure reliability of the method used in making fiber determinations, the maximum difference between duplicate samples and the coefficient of variation between duplicate samples of the clones were calculated for each cross separately. The results are presented in Table 1. As shown in the table the maximum difference found between duplicate samples was 0.2 of one per cent in two of the crosses and 0.3 of one per cent in the other five crosses. This indicates that extremely small differences occurred between the duplicate samples of each clone. This can be emphasized further by the fact that duplicate fiber determinations were made from a total of 894 clones in the experiment. Among these 894 clones the largest difference between any duplicate samples in percentage of fiber was 0.3 per cent.

As would be expected from the small range between duplicate samples, a low coefficient of variation occurred between duplicates. The coefficients of variation between duplicate determinations ranged from 1.5 to 2.1 per cent, with an average of about 1.8 per cent. Thus, both the range and coefficient of variation between duplicate determinations of fiber content showed that very small differences occurred. These results indicate that both the method of sampling the bagasse and the procedure used in determination of fiber in the bagasse were highly accurate and reliable even though they were designed to permit rapid measurement of large numbers of clones.

As expected, a somewhat wider range was found in the fiber percentage among the different plots of the parent clones planted in the experiment than between duplicate determinations of the same clone. Altogether, 11 parent clones were grown in the experiment, with from three to 7 five foot plots of each clone. The smallest difference among plots of the same parent clone was 0.5 per cent and the largest difference among plots of the same parent clone was 2.3 per cent. The average coefficient of variation among plots of the same parent clone was 5.1 per cent. Thus, the average coefficient of variation among five foot plots of a clone was almost three times greater than the average coefficient of variation between duplicate determinations. This greater variation is due to soil heterogeneity or other environmental factors which caused plot to plot variation in fiber percentage.

However, even the variation among plots within clones of the parents due to location effect was comparatively low, as indicated by the coefficient of variation of 5.1 per cent. This means that the effect of environment on variation among the unreplicated five foot plots of the experimental clones was relatively small and that even small differences among the clones in fiber percentage were probably significant.

A crude but conservative estimate of the least difference between two unreplicated clones required to be significant at the 5 per cent level of probability was made from the parent clones and proved to be about two per cent. Thus any difference between two experimental clones of two per cent or greater in fiber percentage can probably be assumed to represent a true difference. This same reasoning could probably be applied in a cane breeding program in which fiber percentage was determined for a large number of unreplicated clones.

## Correlation of Fiber Percentage with Other Characters

Correlation coefficients were calculated between per cent fiber in the cane and the following characteristics: per cent bagasse in the cane, per cent fiber in the bagasse, number of stalks per stool, erectness of the plants, stalk diameter, field Brix and sucrose percentage. Separate r values were obtained for each cross. The results are presented in Table 2. The various correlations will be discussed separately.

<u>Per cent fiber in cane and per cent bagasse in cane.</u>

All the seven crosses showed highly significant (1% level) positive correlation between per cent fiber and per cent bagasse in the cane. The range for r values was from .43 to .88. Out of seven crosses, five gave r values above .77 while two, cross number 11 and 49 gave r values of .43 and .60, respectively. Two crosses, out of seven, one with maximum and the other with minimum r value are depicted in scatter diagrams, Fig. 1 and 2.

In cross 74 (Figure 1) which had an r value of .88 between per cent fiber and per cent bagasse in cane, 34 clones, or 24% of the population, had percentage of bagasse below 28. Of these 34 clones, 21, or 62%, had less than 12% fiber while 13, or 38%, had more than 12% fiber. This means that, if selection had been based on low per cent of bagasse in the cane only, 62% of the clones selected would have had less than 12% of fiber and only 38% of the selections would have had more than 12% of fiber. This indicates that selection for low per cent bagasse alone among a large number of clones in this cross would have been moderately effective in obtaining low fiber clones.

By another means of comparison, there were 37 clones in the total of 143 contained in cross 74 which had fiber percentages below 12 and could be considered as the most desirable clones in respect to fiber content. It is of interest to determine how many of these superior clones would have been kept if selection had been based on low percentage of bagasse. If among the 143 clones only those which had 29% or lower bagasse had been selected, or a total of 44 clones, then 27 of the 37 lowest fiber types (73%) would have been included and only 10 superior clones would have been lost.

Also, the percentage of superior clones (less than 12% fiber) in the entire unselected population of cross 74 was 26%. By selecting in the population of all clones with 29% or lower bagasse, the percentage of low fibered clones would have been raised to 61%.

Cross 11, in which the r value between per cent of fiber and per cent of bagasse in the cane was lowest (+ .43), would be expected to show a lower degree of effectiveness for selection of low fiber clones by choosing those low in per cent of bagasse. From cross 11, 83 clones were grown and tested for fiber and bagasse content. Among the 83 clones tested in this cross 39 had less than 12% fiber, indicating that in the unselected population 47% of the clones were superior in the respect to fiber content. If all clones with 31% or lower bagasse content had been selected, a total of 33 clones, 23 clones with less than 12% fiber would have been obtained. This represents 70% of the clones selected for low bagasse content. Thus, the percentage of superior, low fiber clones in the original population of 47% would have been raised to 70% among the 33 clones with low bagasse content. Although the increase in percentage of low fiber clones would not have been as great in cross 11 as in cross 74, in cross 74 the increase was from 26% to 61% while in cross 11 it was from 47% to 70%, the improvement in fiber content through selection for low bagasse percentage would still have been moderate and worthwhile.

Since most of the correlation coefficients among the seven crosses between fiber content and bagasse content was similar to that found in cross 74, or above .70, the results indicate that selection for low percentage of bagasse would be reasonably effective in obtaining clones with low fiber content. If a number of clones too large to permit testing for actual fiber percentage were grown, the results of this experiment indicate that selection on the basis simply of low bagasse content among the clones can be recommended. The measurement of bagasse percentage would be rapid and convenient since it involves only weighing of cane and weighing of bagasse as it comes from the mill. Such a procedure would not be as valuable as actual determinations of fiber content but should prove worthwhile provided a relatively large population of the clones are kept for further evaluation of fiber content. Selection will be more effective in some crosses than in others but can be recommended for all. Of course, some low fiber clones would still be lost by this procedure. But the percentage of low fiber clones in a population selected for low bagasse content will be appreciably higher than in an unselected population.

Table 1. Maximum differences and coefficients of variation between duplicate determinations of fiber percentage for clones in seven crosses of sugarcane.

| Cross No. | Range (%) | Coefficient of variation (%) |
|---|---|---|
| 11 | 0.2 | 2.1 |
| 15 | 0.3 | 1.9 |
| 32 | 0.3 | 2.0 |
| 49 | 0.3 | 1.7 |
| 72 | 0.3 | 1.8 |
| 74 | 0.2 | 1.5 |
| 148 | 0.3 | 1.9 |

Table 2.--Correlation of fiber per cent in cane with other characters.

| Characters<br>Per cent fiber in cane and | Correlation coefficient in cross number<br>11 | 15 | 32 | 49 | 72 | 74 | 148 |
|---|---|---|---|---|---|---|---|
| Per cent bagasse in cane | .427 | .861 | .784 | .603 | .812 | .874 | .777 |
| Per cent fiber in bagasse | .611 | .647 | .719 | .597 | .906 | .612 | .705 |
| Erectness of stalk | -.066 | .039 | -.124 | -.031 | -.094 | .012 | .104 |
| No. stalks per stool | .111 | .119 | .262 | .218 | .399 | .205 | .166 |
| Stalk diameter | -.120 | -.273 | -.374 | -.408 | -.082 | -.287 | -.348 |
| Field Brix | .383 | .313 | .353 | .142 | .323 | .252 | .490 |
| Sucrose | .494 | .249 | .547 | .686 | .289 | .192 | .482 |
| Significant r (.05) | .217 | .174 | .159 | .195 | .174 | .159 | .205 |
| Significant r (.01) | .283 | .228 | .208 | .254 | .228 | .208 | .267 |

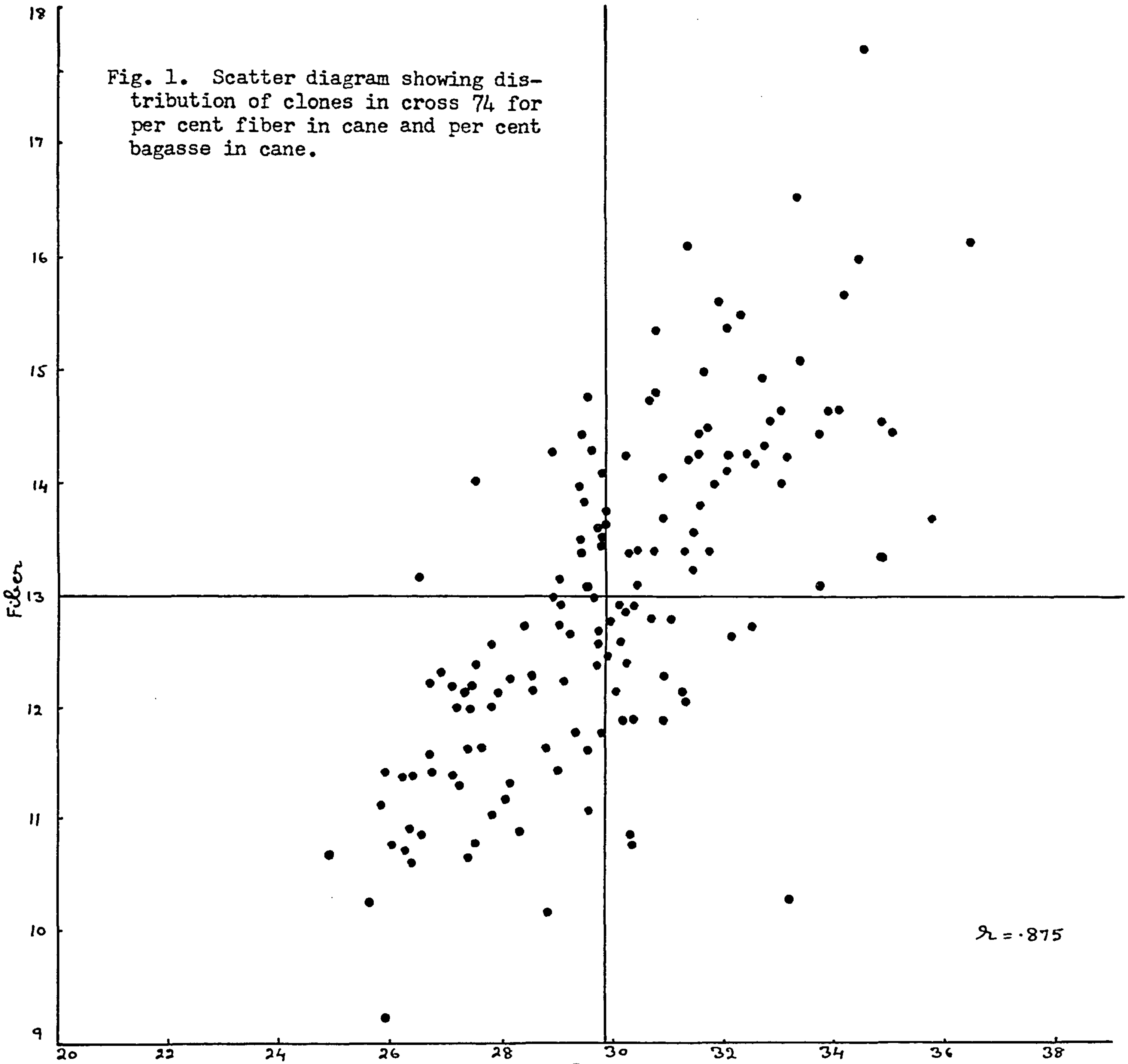



Fig. 1. Scatter diagram showing distribution of clones in cross 74 for per cent fiber in cane and per cent bagasse in cane.

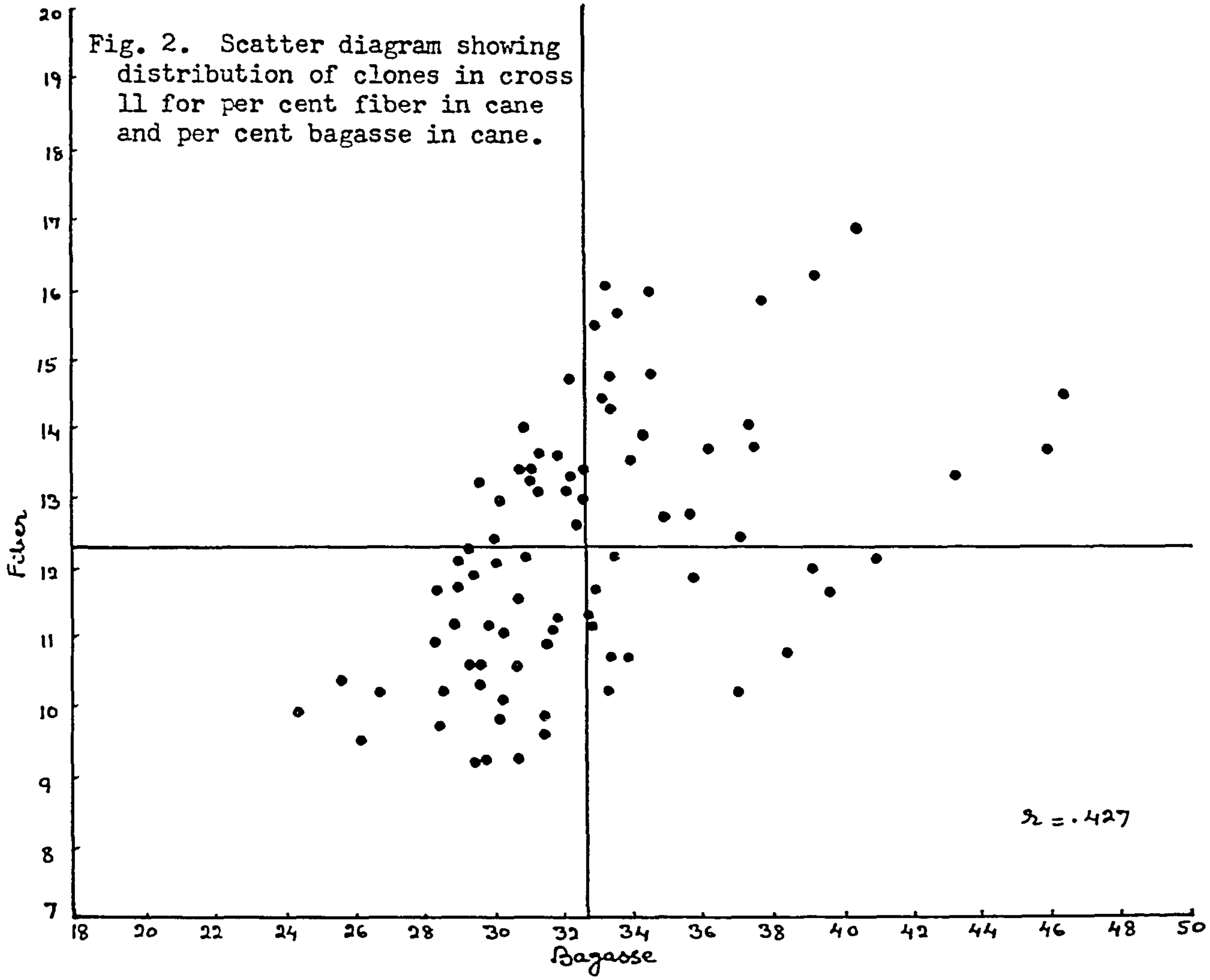



Fig. 2. Scatter diagram showing distribution of clones in cross 11 for per cent fiber in cane and per cent bagasse in cane.

## Per Cent Fiber in Cane and Per Cent Fiber in Bagasse

In all of the seven crosses studied fiber per cent in cane and fiber per cent in bagasse showed highly significant (1% level) positive correlations. (Table 2). The r values for the crosses ranged from .597 in cross number 49 to .906 in cross number 72. A positive association was expected between these characters. It merely indicates that the proportion of the weight of bagasse that is composed of fiber is relatively constant for different clones. Despite the strong correlation found, the association does not seem to have any application in sugarcane breeding since all of the tedious steps involved in measuring fiber per cent in cane are also necessary in measuring percentage of fiber in the bagasse.

Perhaps the most interesting thing concerning the correlations between per cent fiber in cane and per cent fiber in the bagasse is that some were far from perfect even though all were significant. Four of the seven r values were below .7. Failure to find a more complete association between these characters is probably caused by many factors. One of these would be variation in percentage of water in the cane that is extracted in milling. Another factor is the possibility that the percentage of soluble solids in the juice of the cane is not the same as in the juice left in the bagasse after milling.

## Per Cent Fiber in Cane and Erectness of the Stalk

There was no significant correlation in any of the seven crosses between fiber per cent in cane and erectness of the stalk (Table 2). In the total of seven crosses, three, crosses number 15, 74 and 148, showed a positive trend while the remaining four crosses, 11, 32, 49 and 72, showed negative tendency. Cross number 11, which had an r value of -.066, is presented as a scatter diagram in Fig. 3.

In cross 11, 35 clones, or 42% of the population had erectness of the stalks of "very superior" and "superior" types, classes 1 and 2. Of these 35 clones, 16, or 45.7% had less than 12% fiber while 19, or 54.3% had fiber content 12% or above. This means that, if selection had been based on "very superior" and "superior" types of stalks, 45.7% of the clones selected would have had less than 12% of fiber while 54.3% would have had more than 12% of fiber. This indicates that selection for erectness of the stalks even among large number of clones in this cross would have had no effect on fiber content of the clones.

It appeared possible that high fiber content might prove to be associated with erectness of the stalks as a high proportion of fibrous material in the stalk might conceivably make the stalk more resistant to lodging. It is fortunate for sugarcane breeding that an association of this type does not exist since it would have made selection of low fibered, erect type more difficult.

Lack of association between percentage of fiber and erectness of stalks in all of the seven crosses seems to establish conclusively that no detrimental correlation is likely to be encountered in any crosses being made in current sugarcane breeding programs of the United States.

Per Cent Fiber and Number of Stalks per Stool

Out of seven crosses, four, cross number 32, 49, 72 and 74, showed positive significant correlations between per cent of fiber and number of stalks per stool, while crosses 11, 15 and 148 had positive but non-significant correlations. Of the four crosses which were significant, two, crosses number 32 and 72, were significant at 1% level of probability while crosses number 49 and 74 were significant at 5% level of probability (Table 2). The results mean that clones with low fiber content tend also to have a small number of stalks per stool. However, all the significant correlation coefficients were low, ranging from +.205 to +.399, and indicate only a loose association between the characters.

A scatter diagram of cross 32, with $r = +.262$, for per cent of fiber and number of stalks per stool is shown in Fig. 4. Among the 144 clones in cross 32, there were 46, or 32%, with fiber content of 12% or lower, which would be considered superior in fiber percentage. On the other hand if only the clones with 13 or more stalks per stool are considered, the percentage of superior, low-fibered clones was only 18%. Thus, the percentage of low-fibered clones in the entire population was 32 while the percentage among the clones with a large number of stalks was reduced to 18. However, it is of interest that eight of the 144 clones in cross 32 were low in fiber and high in number of stalks per stool.

The positive correlation between per cent of fiber and number of stalks per stool will cause some difficulty in a breeding program in which selection is practiced for low fiber content and high stalk number. The difficulty will be more serious in some crosses than in others. However, it is still possible to obtain clones which represent the extremes for both characters.

An explanation of the positive correlation between fiber per cent and number of stalks per stool is probably found in relationship among fiber percentage, number of stalks per stool and stalk diameter. This relationship will be discussed in the following topic.

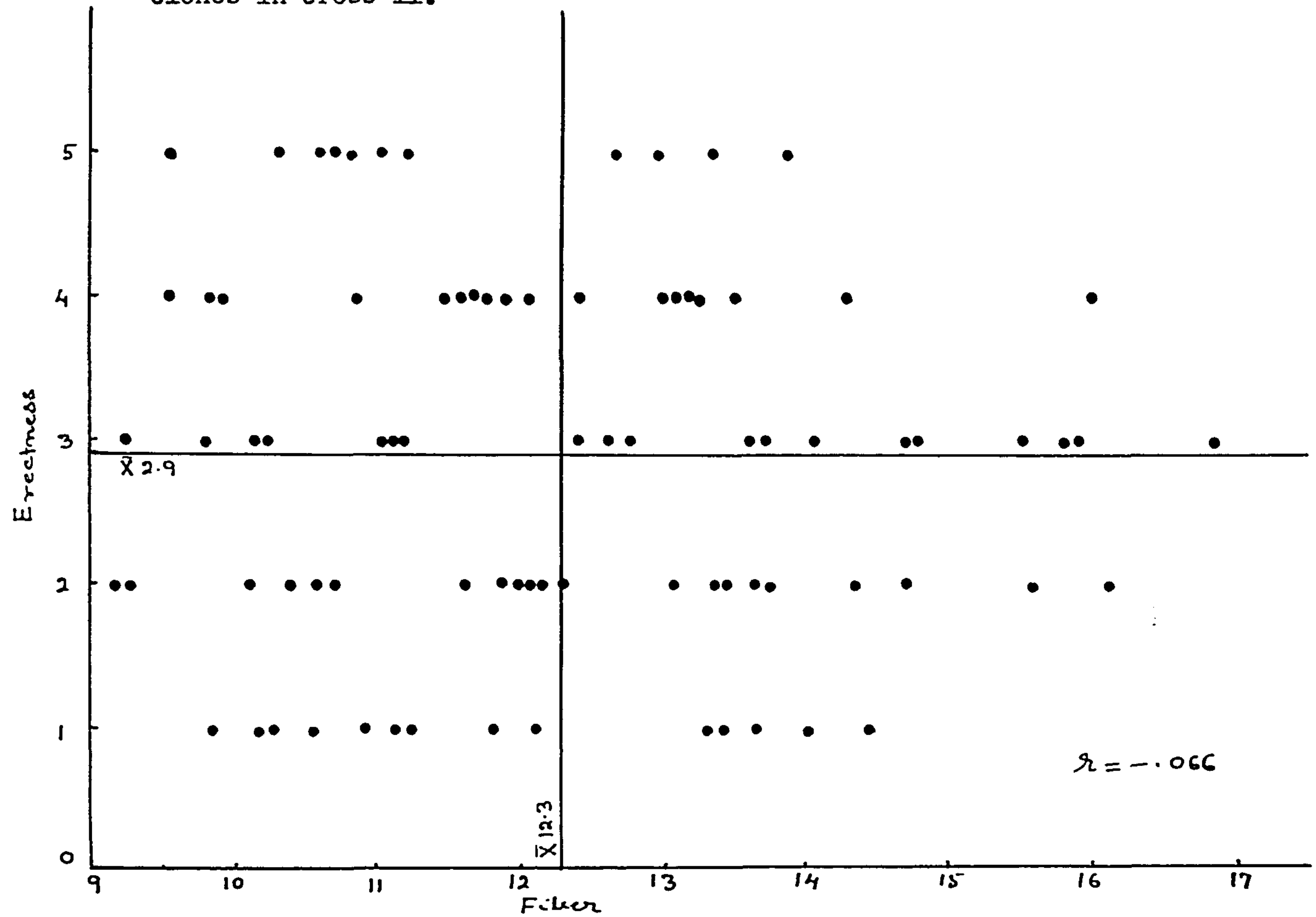
## Per Cent of Fiber in Cane and Stalk Diameter

In the total of seven crosses, five showed significant association while two, cross number 11 and 72 were nonsignificant for fiber per cent in cane and stalk diameter (Table 2). In all crosses the correlation coefficients were negative. All the five crosses, 15, 32, 49, 74 and 148 were significant at 1% level of probability. The significant r values ranged from -.273 to -.408. For a comparative study, two crosses, cross number 32, which had an r value of -.374 and cross number 72 with the lowest (-.082) r value are presented in scatter diagrams, Fig. 5 and 6.

In cross 32 (Figure 5), which had an r value of -.374 between per cent fiber and stalk diameter, 60 clones, or 42% of the population, had stalk diameter of 23 m.m. or more. However, among the clones with low fiber content (12% or lower) the per cent of clones with stalk diameter of 23 m.m. or more was 59%. Thus, in cross 32 there were considerably more large diameter clones proportionately among the low fibered types than in the entire population. An association of this type and degree would be an advantage in a cane breeding program involving selection for a combination of low fiber content and large diameter of stalk. In fact, 19% of the population of cross 32 had both low fiber and large diameter of stalk.

Cross 72, in which the r value between per cent of fiber and stalk diameter was lowest (-.082) would be expected to show a lower degree of association between the characters than in cross 32. The scatter diagram for this cross is presented in Fig. 6.

Figure 3.--Scatter diagram for fiber per cent and erectness of stalks among 83 clones in cross 11.



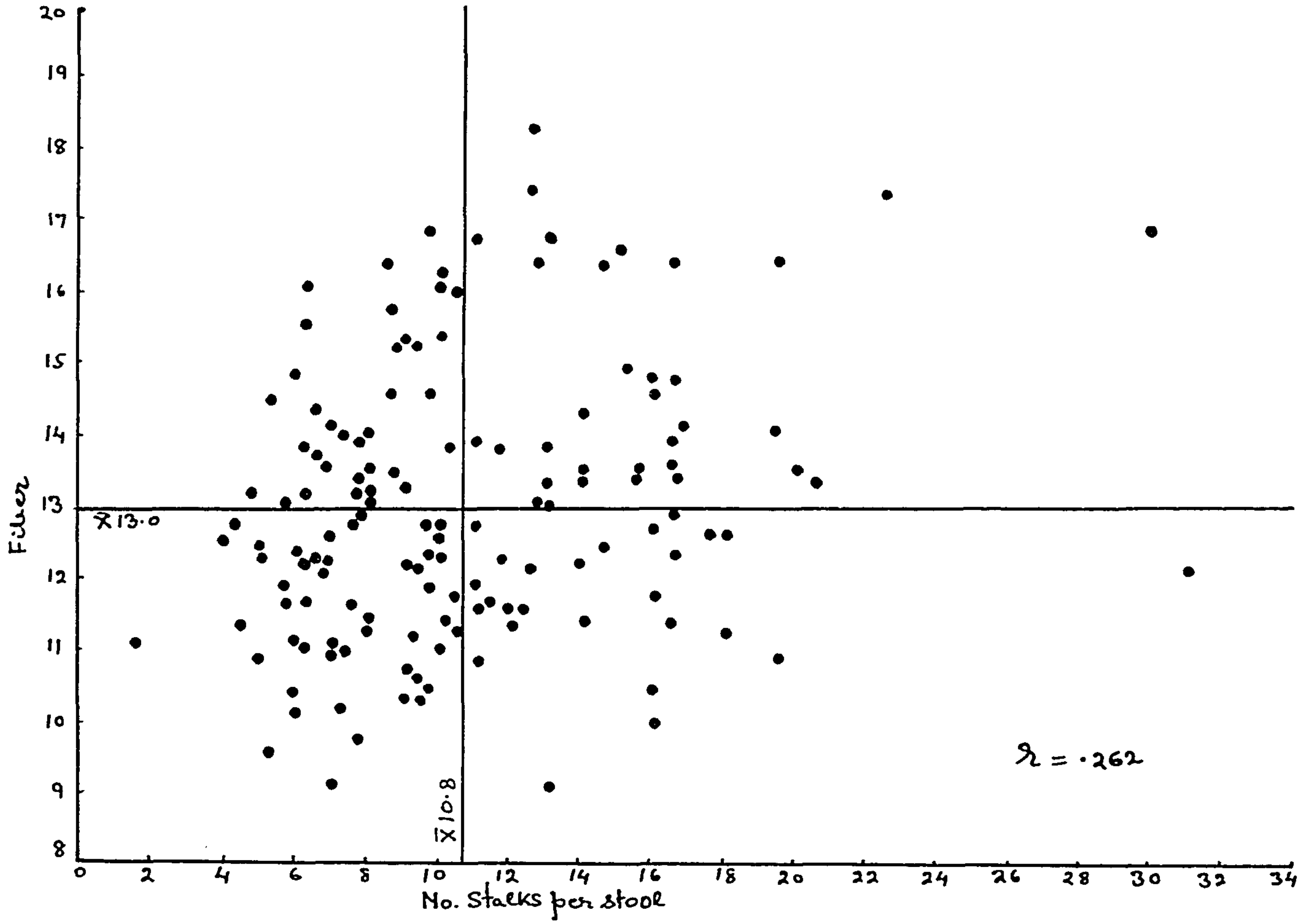



Figure 4.--Scatter diagram for fiber per cent and number of stalks per stool among 144 clones in cross 32.

From cross 72, 138 clones were grown and tested for per cent fiber and stalk diameter. Among the 138 clones tested in this cross 56, or 40%, had stalk diameter of 26 m.m. or above. In comparison, the percentage of clones with stalk diameter of 26 m.m. or above among the low fibered clones (12% or less) of cross 72 was 44%. Thus, the percentage of large diameter clones among the low fibered group was essentially the same as in the entire population, indicating no association between the characters. The proportion of clones in this cross which were as low as 12% in fiber and had stalks of 26 m.m. or above was only 9%.

The association between fiber percentage and stalk diameter varies among different crosses. In some crosses, such as 32, 49 and 148, a fairly strong negative correlation will occur making the task of selecting for low fiber and large stalk diameter an easier one while in a few crosses, such as 11 and 72, there will be no association between the traits.

The tendency for a negative association to occur in most crosses between diameter of stalk and percentage of fiber may have two logical explanations. If other factors are equal, in a clone with large stalk diameter proportionately less of the total stalk weight will be rind than in a clone with small diameter. Since the rind is almost entirely fiber, there will be a proportionately lower fiber percentage. There may also be a genetic association between the characters in some crosses. The parents of the crosses in this study, like all sugarcane varieties being grown commercially in Louisiana, were derived from interspecific hybrids involving _Saccharum officinarum_ and _S. spontaneum_. Most of the clones selected from this hybrid possess chromosomes from _S. spontaneum_ as well as _S. officinarum_. As a species, _S. officinarum_ is characterized by large diameter of stalk and low fiber content while S. *spontaneum* has very thin stalks and very high fiber content. Consequently, it is possible that the S. *spontaneum* chromosomes in the material contain genes for both small stalks and high fiber and that the association found is due to linkage.

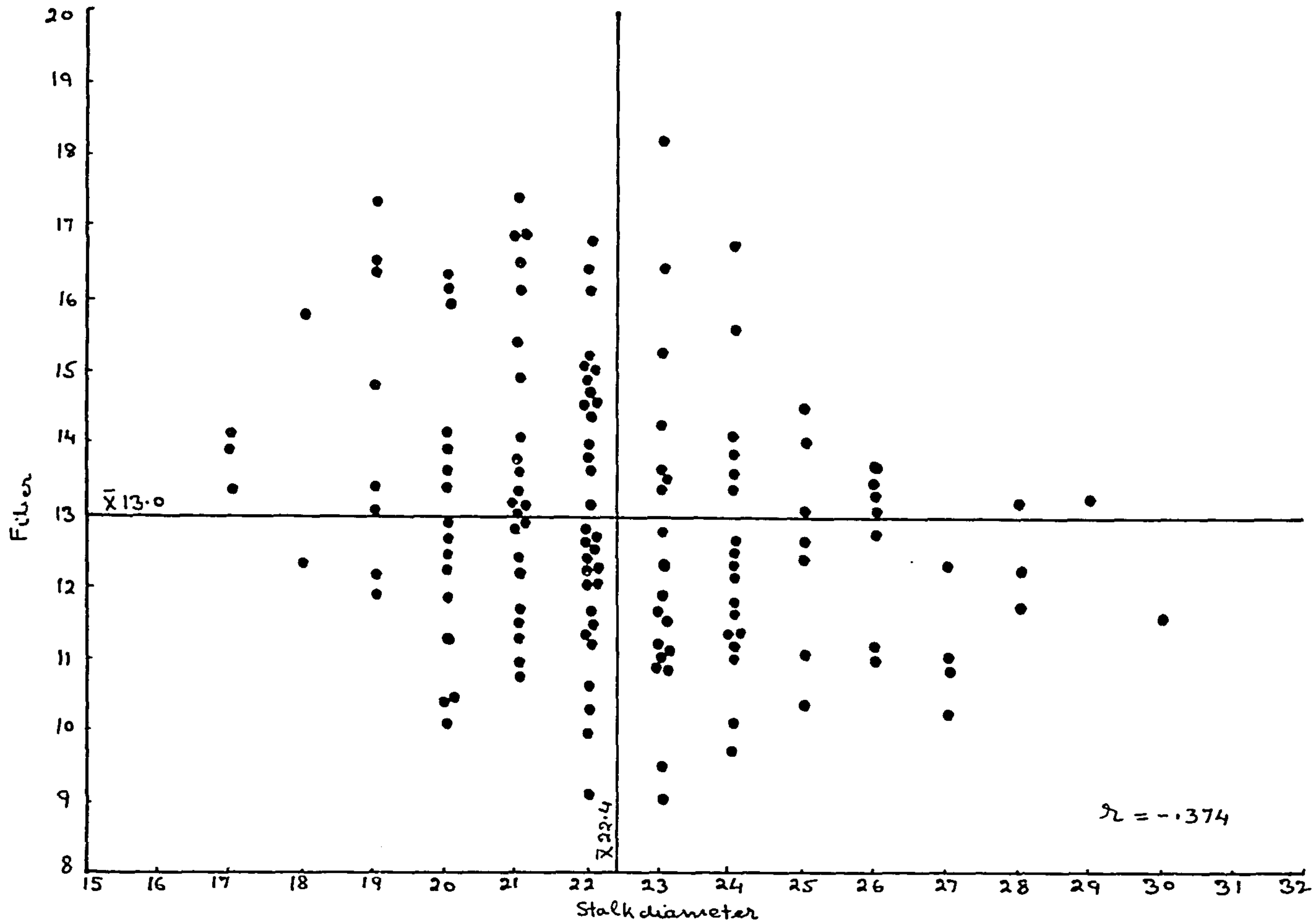
It is probable that the negative association between fiber percentage and stalk diameter caused the positive correlation found in several crosses between fiber percentage and number of stalks per stool. If large stalk diameter leads to a small number of stalks per stool and large stalks also tend to have lower per cent fiber, then fiber content and number of stalks per stool will be correlated through the association of both characters with stalk diameter.

Correlation of Per Cent Fiber with Brix and Sucrose

Probably the most surprising result of the experiment was the positive correlation found between per cent of fiber and Brix as measured in the field and between per cent of fiber and sucrose percentage. Since Brix and sucrose are closely related, these correlations will be presented together. In all of the seven crosses positive correlations were obtained between field Brix and fiber percentage and in all crosses except Cross 49 the r values were statistically significant (Table 2). The significant 4 values ranged from +.252 in cross 74 to +.490 in cross 148. Five of the significant r values were above .30.

The correlation coefficients between fiber percentage and sucrose percentage were similar to those between fiber content and Brix. All were positive in nature and all were significant. The range among these r values was from +.192 to +.686. Thus, there is no question but that a positive

Figure 5.--Scatter diagram showing distribution of clones in cross 32 for per cent fiber and stalk diameter.



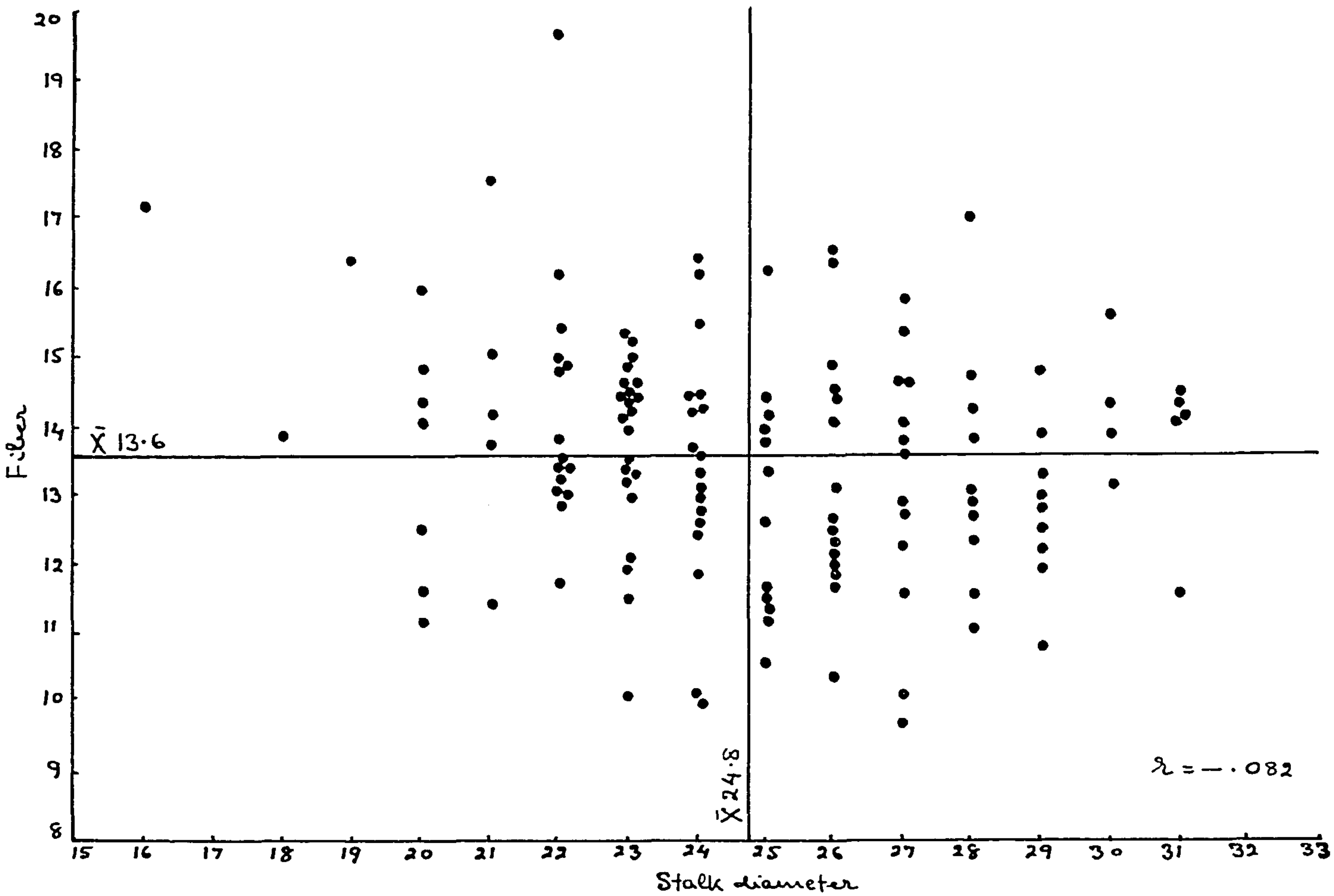



Figure 6.—Scatter diagram showing distribution of clones in cross 72 for per cent fiber and stalk diameter.

association occurs in sugarcane progenies of the type included in this study between per cent of fiber and sucrose content. Clones which were high in sucrose also tended to be high in fiber percentage.

A positive correlation between fiber percentage and sucrose content was not expected. It was expected that any association between these two traits would be negative in nature, high sucrose with low fiber and low sucrose with high fiber. All of the parent clones involved in the seven crosses were developed from interspecific hybridization and contained chromosomes from S. spontaneum as well as S. officinarum. The S. spontaneum parent is characterized by very high fiber and very low sucrose and the S. officinarum parent by low fiber and high sucrose. Consequently, if two traits are associated, the correlation coefficient would be expected to be negative.

The cause of the positive correlation between fiber and sucrose content was not apparent in this study. Hebert did not find any evidence of an association between sucrose content of the same clones and several agronomic characters which he studied, including stalk diameter, number of stalks per stool and erectness of stalks. It is possible that in some manner the tendency to deposit a high concentration of sucrose in the stalk after a short period of growth, such as occurs under the sub-tropical conditions of South Louisiana, and high fiber percentage are both associated with some other character not included in this study or that of Hebert. It appears probable that, whatever the cause of the positive correlation may be, it is associated with the S. officinarum chromosomes and that genes on S. spontaneum chromosomes governing fiber and sucrose development do not influence the association between fiber and sucrose. This would permit the correlation to be positive.

Of great importance in sugarcane breeding than the cause of the correlation is the effect it will have on the development of new varieties having low fiber and high sucrose percentage. Obviously, the association will prove to be a handicap since it will, at least, reduce the percentage of low fiber, high sucrose segregates in a cross below what would have occurred if the two traits were independent. In order to evaluate the effect of the association, scatter diagrams were prepared of these characters for cross 49, with an r value of +.686, and for cross 74, with an r value of +.192. These represent the highest and lowest correlation coefficients obtained among the seven crosses.

The scatter diagram for cross 49 is presented in Fig. 7. It is apparent from Fig. 7 that most of the high sucrose clones were also above average in fiber. There were 31 clones above average in sucrose and fiber compared with 18 clones above average in sucrose and below average in fiber. A similar relationship occurred among the low fibered clones. There were 32 clones that were below average in fiber and also in sucrose compared with 18 clones that were below average in fiber but above average in sucrose. If only the 19 clones in the cross which were 12% or lower in fiber are considered, 26% were high in sucrose (14% or higher) while 37% were low in sucrose (11% or below). Also, among the 24 clones which were high in sucrose (14% or higher), only 21% had low fiber while among the low sucrose types (11% or below) 42% had low fiber content.

However, it is also apparent from Fig. 7 that an appreciable number of clones with high sucrose combined with low fiber did occur in cross 49 despite the positive correlation. It can be noted from the figure that seven clones were above 14% in sucrose and had less than 12% fiber. These would be superior clones both in fiber and sucrose content. Thus, the correlation between fiber and sucrose would not prevent the occurrence of low fiber, high sucrose segregates but would cause some reduction in percentage. Crosses 11, 32 and 148 would probably resemble cross 49 in respect to low fiber, high sucrose segregates. In cross 74 (Fig. 8) the correlation coefficient was only .192. Although this r value was significant, it is very low and suggests that a lower association between fiber and sucrose than in cross 49. It can be seen readily in Fig. 8 that the low association between fiber and sucrose in this cross would not cause any difficulty in obtaining low fiber, high sucrose clones. In fact, 15 of the 143 clones in cross 74 were 12% or below in fiber and above 14% in sucrose. The percentage of low fiber, high sucrose clones was almost as high as that of the high fiber, high sucrose clones.

It is not possible to determine in exact terms the handicap that the tendency for a positive correlation between fiber and sucrose will have in sugarcane breeding. As pointed out earlier, even in crosses having an appreciable correlation such as cross 49, superior clones will occur. However, if rigid selection is practiced for high sucrose and only a few high sucrose clones are saved for further testing, most will have high fiber and it may not be possible to obtain desirable types from the few low fiber clones which are selected. This may be an explanation for the difficulty encountered in most breeding programs of obtaining superior clones with low fiber percentage despite the fact that in most of the crosses in this study a moderately high frequency of low fiber clones was found. Probably the most effective means of avoiding the complication caused by the association is to be very liberal in the initial selection, whether for low fiber or high sucrose in order to allow for the possible low frequency of the selected clones that will be acceptable in the other characters.

## Breeding Behavior of Fiber Percentage

Performance of the clones in the seven crosses in relation to each other and to the parents was studied in order to obtain information concerning genetic behavior of fiber content that might prove useful in sugarcane breeding programs. For this purpose the mean of the clones in fiber percentage and the proportion of the clones having 12% or lower fiber for each cross were compared with the means of the parents involved in each cross. The parentage, frequency distribution and population mean of each cross are presented in Table 3 and several other types of data useful in comparing the crosses are given in Table 4. Altogether there were 845 clones distributed among the progenies of the seven crosses. The seven crosses involved 49 different clones as parents. Four plots of each parent clone was grown in conjunction with the progenies of a cross.

In preparing the frequency distributions shown in Table 3, class intervals of 1.0% were established with class centers at 9.5 - 21.5. For example all clones in cross 11 with fiber percentages between 9.1 and 10.0, inclusive, were placed in class 9.5, as the class center. Based on this system of classification, the clones in the seven progenies ranged from 9.5 to 21.5% fiber. There was a continuous range in distribution of the progenies within each cross. Each progeny gave a distribution similar to the normal curve, with mean and mode near the center of the variation. Thus, the results in all seven crosses indicate that fiber percentage behaves as

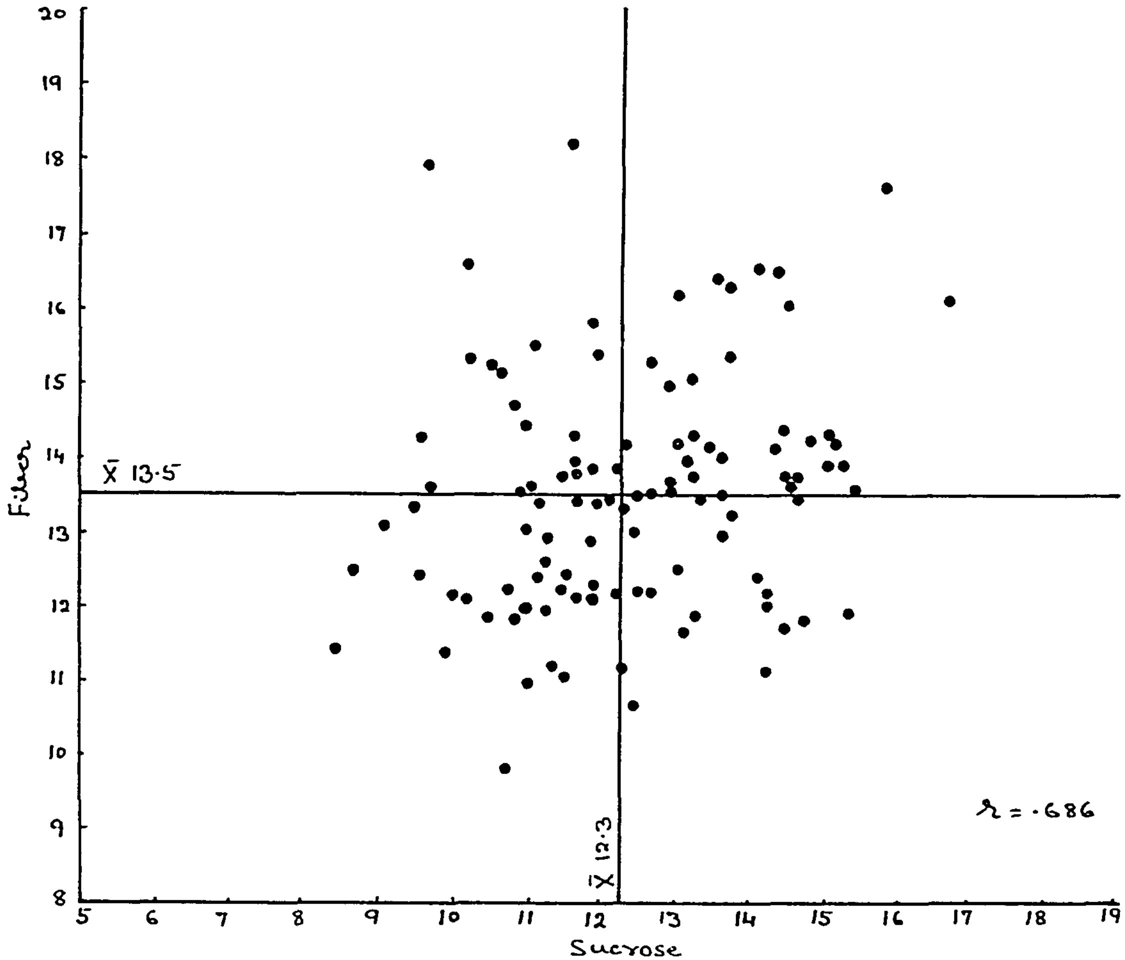



Figure 7.--Scatter diagram showing distribution of clones in cross 49 for per cent fiber and per cent sucrose.

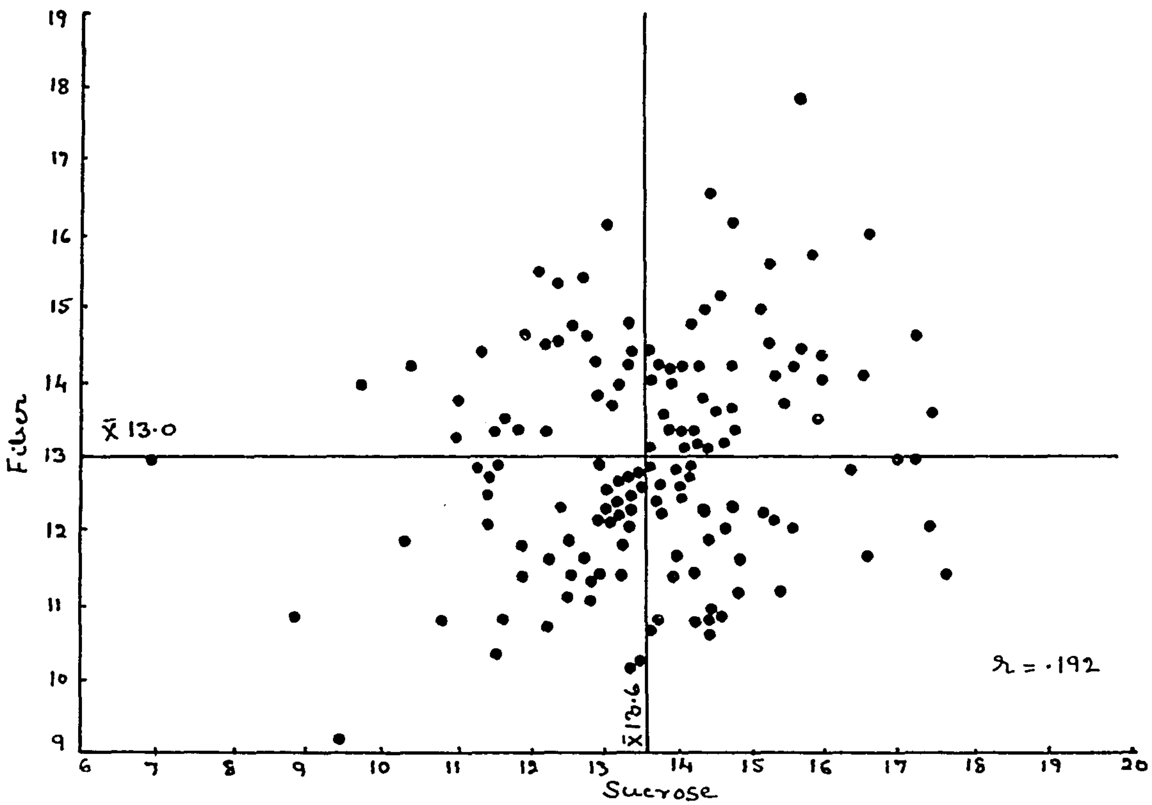



Figure 8.--Scatter diagram showing distribution of clones in cross 74 for per cent fiber and per cent sucrose.

a quantitative character. There appeared to be absence of dominance among the genes affecting fiber content since the average of each progeny did not differ greatly from the average of the parents involved (Table 4).

Another type of evidence which indicates the fiber percentage is quantitative in nature was the fact that among the 11 parent varieties of the crosses an essentially continuous range occurred from a low fiber content of 10.9% in the two parent clones C.P. 30 - 24 and C.P. 43 - 64 to a very high fiber percentage of 17.4 in parent clone C.P. 47 - 191. Thus, there was no evidence among the parents that fiber percentage occurs in a limited number of qualitative classes.

Because of the quantitative nature of fiber content, it is apparent that the number of genes segregating in any cross and the nature of gene action governing fiber content can not be determined. A second factor which complicates genetic analysis of the data is the heterozygous nature of the parents. Each parental clone used in the crosses is undoubtedly highly heterozygous for genes affecting fiber percentage. Furthermore, the fiber content of the parents and progenies is probably influenced by gene present in S. spontaneum as well as S. officinarum chromosomes. Such genes will not undergo normal Mendelian segregation since the chromosomes of the two species do not appear to pair. However, in spite of the difficulties it should be possible to draw certain general conclusions that are reasonably reliable concerning the genetic behavior of fiber in sugarcane.

One of these general conclusions that is warranted is the seven crosses behaved differently in segregation for fiber content. The progeny means varied from a low of 12.3% in cross 11 to a high of 15.7% fiber in cross 148. As further evidence of differences among the crosses, the percentage of clones in a progeny with 12.0% or lower fiber showed a wide range also, from only 3.1% in cross 148 to 49.4% in cross 11. Thus, some crosses were distinctly superior to others in proportion of the progeny which would be desirable in a cane breeding program.

Another fact of importance was the high frequency in which the parent types were recovered in each of the progenies, including the lower fibered parent in each cross. Among the seven progenies, from about 20% to 50% of the clones in a progeny were as low in fiber content as the lower parent. For example, in cross 11 about 43% of the progeny were as low as the low fiber parent C.P. 34 - 139, which had an average fiber per cent of 12.0. This information should be valuable as it indicates that in crosses now being made in breeding programs, types like the lower fiber parent will be recovered even though the progeny may be small and as many as 20 - 50% of the offspring should be as low in fiber as this parent. These results suggest that the parent clones do not differ in a large number of major genes for fiber development but, for reasons cited earlier, the type of material does not permit as estimation of the approximate number of genes in any cross. From the practical standpoint, however, it is of interest that a high percentage of low fibered clones were found in most of the crosses.

Another result of considerable significance was the occurrence of transgressive segregation for fiber percentage in all crosses. In each cross clones with fiber percentage of 2.0 to 2.5% below the lower parent and others higher than the high parent were obtained. For example, in cross 11 one parent had fiber percentage of 12.0 while the other parent was 13.8. Among the progeny of this cross clones as low as 9.5 and as high as 16.5% fiber were found. Some of the very low and very high clones may have been influenced by environmental conditions and may not actually represent transgressive segregates. However, as brought out in the first section of the Results of this study, there was relatively little plot to plot variation in fiber content and the fiber percentage values for the clones within progenies are highly reliable. Since many of the progenies were 2.0 to 3.0% below or above the parents in fiber content, there is no doubt that a considerable degree of transgressive segregation occurred. This high degree of transgressive segregation is expected for any quantitative character, such as fiber content, in sugarcane. The parent clones are all heterozygous and each contains genes for low fiber as well as genes for high fiber. The fiber percentage of a clone probably depends on the relative number of each type of gene rather than whether genes for low or high fiber are present. Because of the presence in each parent of genes for both high and low fiber, segregates can occur in a cross with fiber content higher than either parent through gene recombination. The same explanation will also account for segregates with fiber below that of either parent.

The common occurrence of transgressive segregation for fiber per cent has significance in sugarcane breeding. It can be anticipated that in most crosses segregates with fiber percentage below that of the low parent will be obtained.

Perhaps the most important single fact derived from this study was the close relationship between fiber content of the parents and the fiber content of the progeny from a cross. This close agreement between parents and progeny is shown in Table 4. If the seven crosses are ranked on the basis of the average fiber percentage of the parents beginning with the lowest value, the order is 32, 74, 11 and 49 (tied), 15, 72 and 148. If the crosses are then ranked on the basis of the average fiber percentage of the entire progeny beginning with the lowest value, the order is 11, 32 and 74 (tied), 49, 72, 15 and 148. Also, if the crosses are ranked on the basis of the percentage of the progeny that has 12.0% or lower fiber, the order is 11, 32, 74, 72, 49, 15 and 148. The last basis is probably the most valuable for determining importance of a cross as it expresses more reliably the actual value of a progeny. By any method of comparison, however, the three crosses 11, 32 and 74 were superior to the others in having progenies with low fiber content. These three crosses also had parents with the lowest average fiber percentage. Thus, the superiority of these three crosses in respect to low fiber could have been predicted reliably simply from a knowledge of the average fiber percentage of the parents. On the other hand cross 148 had a progeny with the highest mean fiber content and also had the lowest percentage of clones 12.0% or below in fiber. Both Tables 3 and 4 reveal that cross 148 was distinctly inferior in fiber content of its progeny. Significantly, cross 148 involved two high fiber parents and had the highest average fiber content of its parents of any in the test. The inferiority of cross 148 could have been predicted from a knowledge of the high average fiber percentage of its parents. Also, it could have been predicted from the average fiber percentage of the parents that crosses 49, 15 and 72 would be mediocre in respect to fiber content of their progenies.

It would appear from the results in this experiment that the highest proportion of low fibered progeny can be obtained from crosses between two low fibered parents. A high fibered variety can be used in crosses provided the other parent has low fiber percentage. Crosses in which both parents have high fiber are virtually useless for obtaining types with low fiber.

Thus, in any cross provision should be made to assure that at least one parent has low fiber. Crosses in which both parents are intermediate in fiber will probably prove usable but only mediocre.

The lowest fiber percentage found in any of the 845 clones tested was 9.1. It can be noted in Table 3 that only 19 of the clones had less than 10.0% fiber. It appears from the results of the present study that the minimum fiber percentage obtainable in sugarcane is about ten per cent.

Table 3.—Parentage, frequency distributions and means of progenies for fiber percentage of clones from seven crosses in sugarcane.

| Cross No. | Parentage | Number of Clones in Fiber Class 9.5 | 10.5 | 11.5 | 12.5 | 13.5 | 14.5 | 15.5 | 16.5 | 17.5 | 18.5 | 19.5 | 20.5 | 21.5 | Total Number of Clones | Mean of Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | C.P. 36-105<br>C.P. 34-139 | 9 | 16 | 16 | 11 | 17 | 7 | 5 | 2 | - | - | - | - | - | 83 | 12.3 |
| 15 | C.P. 38-34<br>C.P. 36-105 | 1 | 7 | 13 | 30 | 25 | 20 | 18 | 13 | 5 | 1 | - | - | - | 133 | 13.8 |
| 32 | C.P. 36-105<br>C.P. 30-24 | 5 | 16 | 25 | 30 | 31 | 14 | 7 | 13 | 2 | 1 | - | - | - | 144 | 13.0 |
| 49 | C.P. 29-103<br>C.P. 33-224 | 2 | 2 | 15 | 23 | 32 | 14 | 10 | 7 | 2 | 1 | - | - | - | 108 | 13.5 |
| 72 | C.P. 33-224<br>C.P. 48-126 | 1 | 7 | 18 | 25 | 29 | 38 | 9 | 7 | 3 | - | 1 | - | - | 138 | 13.6 |
| 74 | C.P. 43-64<br>C.P. 44-154 | 1 | 15 | 24 | 36 | 27 | 29 | 7 | 3 | 1 | - | - | - | - | 143 | 13.0 |
| 148 | C.P. 43-33<br>C.P. 47-191 | - | - | 3 | 8 | 10 | 15 | 21 | 17 | 11 | 5 | 2 | 2 | 2 | 96 | 15.7 |

Table 4.—Relationship between fiber content of parents and fiber content of progeny derived from seven crosses in sugarcane.

| Cross No. | Mean of Progeny | % Clone in Cross with 12% or Less Fiber | % Fiber in Parents | Mean of Parents | Type of Cross* |
|---|---|---|---|---|---|
| 11 | 12.3 | 49.4 | 13.8 x 12.0 | 12.9 | I x L |
| 15 | 13.8 | 15.8 | 12.8 x 13.9 | 13.4 | I x I |
| 32 | 13.0 | 31.9 | 13.6 x 10.9 | 12.3 | I x L |
| 49 | 13.5 | 17.6 | 11.7 x 14.1 | 12.9 | L x H |
| 72 | 13.6 | 18.8 | 13.6 x 15.6 | 14.6 | I x H |
| 74 | 13.0 | 28.0 | 10.9 x 14.4 | 12.7 | L x H |
| 148 | 15.7 | 3.1 | 14.3 x 17.4 | 15.9 | H x VH |

* L - Low in fiber (12.0% and below)

I - Intermediate in fiber (12.1 - 14.0%)

H - High in fiber (14.1 - 16.0%)

VH - Very high in fiber (16.1 or above)

# SUMMARY

In order to study the breeding behavior of fiber content in sugarcane seven crosses involving eleven parents were studied. The entire experiment was divided into three categories, (1) reliability of fiber determination, (2) correlations of fiber percentage with other characters and (3) breeding behavior of fiber percentage among the seven crosses.

## I. Reliability of Fiber Determination

In the total of 894 clones, including 49 clones of parents, studied, the maximum difference found between duplicate samples was 0.2 of one per cent in two of the crosses and 0.3 of one per cent in the other five crosses. This indicates that extremely small differences occurred between the duplicate samples of each clone. The coefficients of variation between duplicate determinations ranged from 1.5 to 2.1 per cent, with an average of about 1.8 per cent. This indicated that both the method of sampling the bagasse and the procedure used in determination of fiber in the bagasse were highly accurate and reliable.

Altogether, 11 parent clones were grown in the experiment, with from 3 to 7 five foot plots of each clone. The smallest difference among the same parent clone was 0.5 per cent and the largest was 2.3 per cent. The average coefficient of variation among the plots of the same parent

clone was 5.1 per cent. The greater variation than between duplicate samples was due to soil heterogeneity or other environmental factors which caused plot to plot variation in fiber percentage. The relatively small plot to plot variation, with coefficient of variation of only 5.1 per cent, indicates that environmental variation among unreplicated five foot plots of the clones was relatively small.

## II. Correlation of Per Cent Fiber and Other Characters.

Per cent fiber in cane and per cent bagasse in cane.

All of the seven crosses studied for this character were statistically significant. The correlations were positive. The results indicate that selection for low percentage of bagasse would be reasonably effective in obtaining clones with low fiber content. Selection on the basis simply of low bagasse content among the clones can be recommended if the number of clones is too large to permit testing for actual fiber percentage. Selection will be more effective in some crosses than in others but can be recommended for all.

Per cent fiber in cane and per cent fiber in bagasse.

All of the seven crosses studied showed highly significant positive correlations yet the correlations were far from perfect. Though all the correlations were significant, the association does not seem to have any application in sugarcane breeding program since all of the tedious steps involved in measuring fiber per cent in cane are also necessary in measuring percentage of fiber in the bagasse.

Per cent fiber in cane and erectness of the stalk.

There was no significant correlation in any of the seven crosses studied. It is fortunate that an association does not exist between high fiber content and erectness of stalks since it would make selection of low fibered, erect type more difficult.

Per cent fiber in cane and number of stalks per stool.

Out of seven crosses, four were significant showing positive association while three were nonsignificant. This positive correlation will cause some difficulty in a breeding program in which selection is practiced for low fiber content and high stalk number. In some crosses this difficulty will be more serious than others. However, it is possible to obtain clones which are low in fiber and high in number of stalks per stool.

Per cent fiber in cane and stalk diameter.

In the total of seven crosses, five showed significant negative association while two were nonsignificant yet the tendency was negative. The association varies among different crosses. In some crosses a fairly strong negative correlation will occur making the task of selecting for low fiber and large stalk diameter an easier one while in a few crosses there will be no association between the traits.

Correlation of per cent fiber with Brix and sucrose.

Six out of seven crosses showed positive significant association between fiber per cent and Brix while all the seven crosses showed positive significant association for per cent fiber and sucrose. This association will prove a handicap because it will reduce the percentage of low fiber, high sucrose clones in crosses below what would have occurred if the two traits were independent. This will cause difficulty in breeding programs of obtaining superior clones (high in sucrose) with low fiber content. If rigid selection is practiced for high sucrose and only a few high sucrose clones are saved for further testing, most will have high fiber and it may not be possible to obtain desirable types from few low fiber clones which are selected.

## III. Breeding Behavior of Fiber Percentage in Cane

In order to obtain information concerning breeding behavior of fiber content in sugarcane frequency distribution, parent and progeny mean and other valuable data were calculated. Each cross behaved differently. Each progeny gave a distribution similar to normal curve, with mean and mode near the center of the variation. There was a continuous range from a low fiber content to high fiber content. This indicates that fiber percentage behaves as a quantitative character. The absence of dominance among genes affecting fiber content was evident since the average of each progeny did not differ greatly from the average of the parents.

There are several factors which renders nearly impossible the task of determining the number of genes governing the fiber content, (1) quantitative nature of fiber content, (2) heterozygous nature of parents and (3) the genes on the chromosomes of _S. spontaneum_ and _S. officinarum_ probably influence the fiber content which will not undergo normal Mendelian segregation. Despite these handicaps certain general conclusions can be drawn. There is a high frequency for the recovery of parent types, including the low fibered parent. These results suggest that the parent clones do not differ in a large number of major genes. A strong degree of transgressive segregation occurred which gave clones 2 - 3% lower in fiber than low parent while some were higher than high fiber parent.

There was a close relationship between the fiber content of the parents and the fiber content of the progeny from a cross. This relationship will help in predicting the behavior of the progeny.

Results indicate that a high fibered variety can be used in crosses provided the other parent has low fiber percentage. Crosses in which both parents are intermediate in fiber will probably prove usable but only mediocre. Crosses in which both parents are high in fiber percentage are useless for obtaining low fiber types.

The results of the present study further indicates that the lowest fiber percentage obtainable in sugarcane is about ten per cent.

## REFERENCES CITED


Abbott, E. V. 1938. Red rot of sugarcane. U.S.D.A. Tech. Bull. No. 641, pp. 96.

Abbott, E. V., E. M. Summers and R. D. Rands. 1936. Disease resistance tests and seedlings selections in 1935 at the U.S. Sugar Plant Field Station, Houma, La. Sugar Bull. 14 (12): 3-7.

Almieida, J. R. and R. Cansglieri. 1941. Fiber in cane variety Co. 290. The International Sugar Journal. XLIII, 510. pp. 188.

Azab, Y. E. 1952. Inheritance of resistance in sugarcane to mosaic and red rot disease. A dissertation submitted in the Louisiana State University for Ph.D. in Dept. Botany, Bacteriology and Plant Pathology.

Brandes, E. W. 1931. Breeding for resistance to mosaic. Facts about sugar. 26: 490-491, 493.

Brandes, E. W. and P. J. Klaphaak. 1925. Breeding of disease resisting sugar plants for Americas. The reference book of the Sugar Indust. of the World. 3: 50-507.

Brandes, E. W. and C. P. Sartoris. 1936. Sugarcane: its origin and improvement. U.S.D.A. Year Book. 1936; 561-624.

Cheesman, E. E. 1927. The scope of genetic research on sugarcane. Trop. Agri., 4:9. Sugar Supplement.

Davies, J. G. and R. D. E. Yearwood. 1946. The estimation of fiber per cent cane. Dept. Sugar Tech., Imperial College of Tropical Agriculture, Trinidad. XLVIII, No. 565, 11-13.

Deer, Noel. 1921. Cane Sugar. Second (revised and enlarged) edition. Norman Rodger, 13-15.

Dutt, N. L. and J. T. Rao. 1951. Progeny tests on inheritance of pith in sugarcane seedlings. Proc. Ind. Sci. Congress, 1951.

Gowgill, H. B. 1918. Studies in inheritance in sugarcane. Jour. Dept. Agri. Puerto Rico. 2: 33-41.

Inniss, B. 1944. Sugarcane mosaic disease in Jamaica and Barbados. B.W.I. Sugarcane Breeding Station (Barbados). Bull. No. 26: 121-122.

Jeswiet, J. 1927. The history of sugarcane selection work in Java. Proc. of the Second Conf. of the I.S.S.T., 1927. 115-122.

Keller, A. G. 1956. Economic bagasse separation. Sugar Journal. 18, 10; 16, 17, 20.

Kerr, H. W. and N. G. Cassidy. 1938. The determination of fiber in cane. The International Sugar Journal. XL, 473; 180-183.

Loh, C. S., P. M. Tseng and T. H. Hu. 1952. Hybrid vigor of sugarcane hybridization. Jour. of Sugarcane Research, 6: No. 2. Published by Taiwan Sugar Expt. Stat. Pingtung Stat., Reprint No. Breeding 20.

McMartin, A. 1949. Present development in the search for new sugarcane varieties for Natal, S. Africa Sugar Jour. 33: 35, 37, 39, 41.

Rands, R. D., E. V. Abbott and E. M. Summers. 1935. Disease resistance tests on sugarcane seedlings and initial selection procedure in the southern United States. Sugar Bull. 13 (24): 10, 12, 14-16.

Spencer, G. L. and G. P. Meade. 1917. A Hand Book for Cane Sugar Manufacturers and their Chemists. Seventh Edition, Revised, Rewritten and Enlarged. John Wiley and Sons, Inc. London. Chapman and Hall Limited, 1917, 329, page 351.

Venkatraman, T. S. 1927. Sugarcane breeding. Indications of inheritance. Mem. Dept. Agri. Bot. Ser., 14 (3): 113-120.

Warner, J. N. 1953. The evolution of a philosophy of sugarcane breeding in Hawaii. Hawaiian Planter's Record. LIV, 3, 139-162.

## AUTOBIOGRAPHY

Mr. Hridaya Nath Singh was born on January 19, 1928 in the village Sakaldiha, district Banaras, U. P., India. He got his High School and Intermediate education from the U. P. Board of High School and Intermediate Education. He was admitted in the Government Agricultural College Kanpur (Agra University), U. P., India in the year 1945, from where he got his B. Sc. (Ag.) degree in the year 1949. He then jointed B. R. College Agra (Agra University), Agra and got his M. Sc. degree in the year 1951 in Agronomy. He was appointed as Senior Scientific Assistant in the Department of Botany at the Central Sugarcane Research Station Bihar, Pusa, India in March, 1952 and worked there till November 30, 1953. He was admitted in the Louisiana State University in February, 1954 in the Department of Agronomy and now is a candidate for the degree of Doctor of Philosophy in June 1956.

## EXAMINATION AND THESIS REPORT

Candidate: H. N. Singh

Major Field: Agronomy

Title of Thesis: Breeding Behavior of Fiber Content in Sugarcane.

Approved:

M. T. Henderson

Major Professor and Chairman

Richard J. Russell

Dean of the Graduate School

EXAMINING COMMITTEE:

St. John P. Chilton

C. W. Edgerton

M. B. Sturgis

Wm H Patrick Jr

Date of Examination:

May 8, 1956